WaterWatch, page 66
Spring Meeting Housing and Registration Forms, page 70

EOS
Transactions, American Geophysical Union
Vol. 65 No. 8 February 21, 1984

Eos, Transactions, American Geophysical Union Vol. 65, No. 8, Pages 65–72 February 21, 1984

Seismology

8170 Structure of the crust and upper mantle
[illegible]

Tectonophysics

8110 Convection currents
THE INTERACTION OF A SUBDUCTING LITHOSPHERIC SLAB WITH A CHEMICAL OR PHASE BOUNDARY
U.R.Christensen (Max-Planck-Institut, Saarstrasse 23, 6500 Mainz, FR Germany), D.A.Yuen
[illegible]

8170 Structure of the crust (Keweenawan Rift)
STRUCTURE OF THE SOUTHERN KEWEENAWAN RIFT FROM COCORP SURVEYS ACROSS THE MIDCONTINENT GEOPHYSICAL ANOMALY IN NORTHEASTERN KANSAS
L. Serpa (Department of Geological Sciences, Cornell University, Ithaca, NY 14853), T. Setzer, H. Farmer, L. Brown, J. Oliver, S. Kaufman, J. Sharp, and D. W. Steeples
[illegible]

8199 Tectonophysics
ORIGIN OF GUYOTS: THE BEAGLE TO SEABEAM
H. W. Menard (Institute of Marine Resources and Scripps Institution of Oceanography, La Jolla, CA 92093)
[illegible]
J. Geophys. Res., B, Paper 4B0152

Volcanology

8599 Volcanology (Volcanic Stratigraphy)
STRATIGRAPHIC RELATIONS AND SOURCE AREAS OF ASH-FLOW SHEETS OF THE BLACK MOUNTAIN AND STONEWALL MOUNTAIN VOLCANIC CENTERS, NEVADA
[illegible]

E. C. Bullard's First Heat-Probe

Elizabeth N. Shor
2655 Ellentown Road, La Jolla, CA 92037

Sir Edward Bullard in 1973 said to me, "Betty, I want to tell you how my first ocean heat-flow instrument was made in the summer of 1949." He was then on his annual 3-month visit to Scripps Institution of Oceanography and knew that I was writing a history of the institution. Teddy (as he preferred to be called) was proud of his participation in measuring the flow of heat at sea. The instrument that he described that day never made a heat-flow measurement, but it did establish the technique that has been used for more than 30 years.

The following account is a slightly shortened version of our taped conversation on August 5, 1973 (the original audio cassette is in the archives of Scripps Institution of Oceanography, item 81–84). Unfortunately, the reader loses the charm of Teddy's voice and accent, but here for history are his words.

Bullard: I first became interested in heat flow in the early 1930's. I'll send you a copy of a paper that describes some of the background of the early work on land [*Bullard*, 1939]. It was the British Association, which is like your triple-A S—had a committee on the subject, with Harold Jeffreys on it. In the period just before the war I was developing methods of making heat-flow measurements on land, which had been done extraordinarily badly before, and hardly anything had been done since about 1880. There was a previous British Association committee way back in the 1880's, and I have written a historical paper on this. The historical paper is in Willie Lee's book on heat flow [*Bullard*, 1965]. He'd asked me to write a summarizing chapter for the book, and I said I wouldn't do that, because it's too dull a thing to do, and then he wrote to me and said he thought this was most unreasonable and improper of me, and he saw no reason why I shouldn't write a summarizing chapter. And so I wrote an historical chapter which was really a sort of joke chapter and was mostly about the study of heat flow in the 17th century. But it does give the more recent stuff.

Well, then, shortly before the war I began to think about measuring heat flow at sea. And the war in '39—the war overtook the plan, and we didn't do anything about it.

Shor: Had you developed an instrument at that time?

Bullard: No, I had developed the ideas for the instrument but we had done no hardware development, but I knew what I wanted to do. And we had two schemes for doing it: one was the one we eventually adopted of putting a spike in, and the other was the idea of putting a kind of mattress on the seafloor and leaving it there and measuring the temperature gradient through it. Then, after the war I couldn't do this because I couldn't get a ship. *Discovery* was being used for replenishing lighthouses, and there was no British oceanographic ship available immediately after the war. Then I tried to get Maurice Ewing to cooperate. He said he couldn't spare any ship time for this purpose. He'd just gone to Lamont. I'd known him—I'd been to sea with him before the war when he was at Lehigh, in connection with seismic work.

Well, then I went to Canada. I took a job in Canada, going up there in March 1948. And in the summer of '48 I paid a brief visit to California. It was my first visit to La Jolla. Louis Slichter used to run a conference on geophysics every year [at the University of California, Los Angeles]. I went to that, and Louis brought me down here afterwards, and I came down here and met Roger Revelle and Walter Munk. My memory is that I went to a party at Roger's, and I met a lot of blondes. I remember La Jolla as being full of blondes.

I got on very well with Walter and Roger. They asked me to come back the next summer. I forget exactly when, but I got a letter inviting me to work for the summer down here, and I said there were several things I'd like to do and one of them was the heat-flow measurement. And I came down here, probably June, July 1949. And I got here and it was suggested that I take on Art Maxwell, who was a graduate student.

Well, anyway, I decided to do two things: to investigate the westward drift of the earth's magnetic field, which was a data analysis problem, and to try and build an apparatus for measuring heat flow. Well, then I went to Roger and said we'd like some workshop time. And Roger said he was sorry, the workshop was completely taken up with urgent work, and it was impossible to give any workshop assistance. So I decided that we'd build the thing ourselves. So I went around to the fellows and I hadn't got any workshop assistance—couldn't we work in the workshop, Art Maxwell and myself? This was obviously a slightly embarrassing matter. But we went down to the old workshop in the old shed. I got an office—I shared an office with Walter Munk, over the old director's office in the original building of Scripps.

Well, we settled down. This was a substantial job. We designed what—it was the first time I think that anyone at Scripps had had a watertight equipment for use in the deep sea. I remember the expert advice from [John D.] Isaacs, and so on, was very much against this. They wanted us to build an equipment that was full of oil — the recorder, the electronics and everything immersed in oil. And I decided against this. I decided to build a watertight apparatus made watertight with O-rings. That was, I think, brand new. And we had some interesting experiences with it.

First of all, we had great difficulty in getting sufficiently strong tubing—alloy steel tubing seemed not to be available in sort of 1-inch thicknesses 6 inches diameter. We eventually found that the people who made ball races—ball bearings—made them by slicing them off steel tubes, and one of the manufacturers of ball bearings and ball races supplied us with a piece of tubing. And we got some end plates out of good alloy. The stuff was about 6 inches internal diameter and about three quarters of an inch thick, something like that. And we made up things out of this, with O-rings. Of course, the O-ring had been introduced originally for aircraft-hydraulic systems during the war and was then introduced into the uranium diffusion plant as a matter of making it pressure tight. And I'd known of it from these sources. And we decided to use this. And it proved extremely effective. We went out and tested these containers, and we never had a leak. I've never had a leak from an O-ring container at sea. They're used in everything now of course. They're used in cameras and seismic equipment and all kinds of things.

And we made a very clumsy apparatus for this purpose. We decided to do something which I thought I understood rather than something I didn't. So we bought—at least I got from the British Admiralty—galvanometers, which were very robust and which could be used horizontally. And we fixed these and used photographic recording and thermocouples. So it was thoroughly old-fashioned equipment: no electronics; photographic recording, galvanometers, reversing switches for eliminating thermal emf's in the equipment. And this equipment I afterwards used myself, so it is the equipment I describe in my first paper [*Bullard*, 1954].

Well, we decided to allow the full pressure to come on the probe itself. So the probe itself was filled with oil, and the recorder was full of air. And we had pressure-tight connections between the two, and—sort of looking back—the whole technique of fitting the connections through—I remember we had a good deal of trouble with getting the connections through, and eventually I decided there was too much advice in the workshop on this, and I took the end plates home. I took this home, and heated it on a gas range and soldered the connections in—little glass connectors with a little metal skirt, and soldered them in.

Shor: Was Art Maxwell working closely on this?"

Bullard: He was working on this—we were both working on the lathe making this thing. Of course, we had to make this photographic recorder; you see, we had to make a photographic camera and all the associated supports and things. Well, anyway, we made this apparatus in the course of about a couple of months. And we took it to sea. We had trouble in getting ship time. What we wanted was a day or two of ship time to go out and test it, you see. We did all the testing. I remember the first testing we did, we built a sort of gallows down at Mission Bay [in San Diego], which was then a marsh, of course—and strung the apparatus up with the galvanometer and things in it and climbed up a ladder and cut the ropes and let it drop to see if it would go into the mud and see whether the shock would break the galvanometer and all this kind of thing. Anyway, we then tried without any galvanometers in to see if we could get it into the mud out in the trough off San Diego. There was a tremendous amount of sort of testing to be done. It was an entirely new thing really.

We discovered the trouble that if you put a thing into the bottom and left it there you couldn't avoid pulling it and bending it, and we tried tubes of various lengths and various diameters, to see what we could do. And we more or less discovered what we could do and what we couldn't do. And finally we took it out for a run with the whole apparatus to try and measure the heat flow—and we got no records at all. Everything worked. Except we didn't get any records. And we spotted what it was. It was condensation on the mirrors of the galvanometer, which we'd not thought of before. So we put drying equipment in and got rid of this. But we never got any results that summer, and I went home [to England]. I was director of the National Physical Laboratory [NPL]. I went home and had another similar apparatus built, and I got results with that.

That was built of course by the NPL workshop. We had some of the best workshop facilities in the world. I was at home. I had superb facilities and no question as to who was going to use them. You see, I was director of an operation spending many millions of dollars a year. If I said do something, they did it. And so I had proper working drawings made of the equipment and had it built in a proper workshop and so on. And we took it out and it worked every time.

Shor: You tested it then off England?

Bullard: Yes, I'd done all the testing here so I just made a new apparatus and took it out to sea and it worked.

Now that's all been published, so the dates on this are all known. I'll give you all the references. Our first paper was published in the *Proceedings of the Royal Society*. You know the two letters in *Nature*, do you?

Shor: No.

Bullard: Well, I'd better find these for you [*Revelle and Maxwell*, 1952; *Bullard*, 1952]. What happened was this. There was a little—well, not exactly a misunderstanding —but I understood that the group here and ourselves were going to publish a joint paper. And I was very busy and I held up publication of our work for some time, and eventually the [Revelle and] Maxwell letter to *Nature* went in, and I put a letter in in the same number. Well, then afterwards we published a joint paper [*Bullard et al.*, 1956]. There was a bit of a muddle about publication.

Do you know—now I come to think of it, the business about taking the thing home to make the go-through connection was at NPL; it was the NPL workshop that was making a scene about go-through connections—pressure-tight connections in heavy plates. And I took it home and did it on my domestic gas range. And I think this rather shook the place, to have the director take home the thing and actually do the soldering when they said they thought they couldn't do it. That was in England. It wasn't here. We did it here without any fuss. We did it ourselves in the workshop.

The workshop manager was very good to us and very nice to us. And eventually, actually, some of the heavy machining was done. I said to him one day, I said, "Look, do you want us doing the heavy machining? These are big lathes. We're not professional mechanics. We're turning considerable material, these alloy steels. Wouldn't you rather do this yourself?" And they did—the actual outer container was machined by the workshop staff in the end. But we machined the rest of the stuff.

Now there is a complete description—the apparatus we had here is essentially the same as the apparatus I built in England.

So that's essentially the story. And then afterwards Art Maxwell, Roger [Revelle], and I wrote a summarizing article on the whole subject. It's a review article about heat flow. The critical things to look at are those two letters in *Nature*, which are the first publications, then there is my paper in the *Proceedings of the Royal Society* describing my own measurements, and there's our joint paper with Roger.

So ended Bullard's verbal summary in 1973.

After the unsuccessful trials of 1949, the original instrument at Scripps Institution was "discarded in favor of using thermistors in a bridge network with an amplifier and home-built recorder," said Arthur E. Maxwell (personal communication, June 21, 1983). He worked with Scripps engineers James M. Snodgrass and John D. Isaacs on the improved model during late 1949 and early 1950. That heat-probe was used on the Midpac (sometimes called Mid-Pacific) Expedition, carried out by the Scripps Institution of Oceanography and the U.S. Naval Electronics Laboratory during the summer of 1950. (The name of this expedition is given incorrectly in *Bullard* [1965] as Capricorn Expedition, which was in 1952.) The first successful oceanic heat-flow measurements were taken on that expedition. (As noted in various of the early papers, Hans Pettersson described oceanic heat-flow measurements that he took in 1948; Bullard considered these invalid.)

Bullard, as he said above, returned to England and in 1952 (or 1951?) at the National Physical Laboratory had an instrument built that was "similar to the original one" [*Bullard*,

Article (cont. on p. 74)

Elizabeth N. Shor *was raised in Lead, South Dakota, attended Pasadena City College (1 year) and Wellesley College (2 years). She has learned a bit about geophysics from George G. Shor, Jr., whom she married in 1950. She has written two books on the history of paleontology, one on the history of Scripps Institution of Oceanography (where George works and she has worked), and a number of biographical accounts of scientists, especially for the* Dictionary of Scientific Biography.

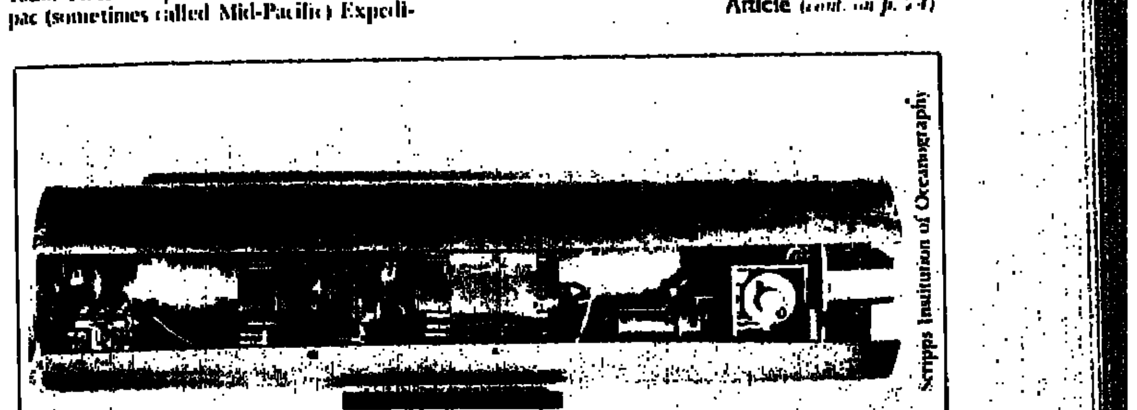


Fig. 1. The heat-probe recorder built in the summer of 1949 by E. C. Bullard and A. E. Maxwell.

Scripps Institution of Oceanography

Forum

Global Positioning Technology

In an otherwise excellent article ("The Impact of VLBI and GPS on Geodesy," *Eos*, September 27, 1983, p. 569), Dr. John D. Bossler inaccurately reports that the Macrometer, a single channel receiver which came to market only last year and is restricted to relative position use was the first global positioning system (GPS) receiver to become commercially available.

As many in the geophysics community know, Stanford Telecommunications, Inc. (STI), has provided GPS receivers and transmitters commercially for almost 5 years.

STI dual frequency GPS Geodetic Recievers, owned and operated by Shell, NSWC, IBM, and Draper Labs have been used in numerous absolute and relative positioning experiments. In one such experiment, analysis of 5 hours of four satellite phase measurements yielded relative position coordinates on a 28-km baseline which were repeatable to 30 cm in height, 50 cm in E-W direction, and 10 cm in N-S direction.

STI GPS recievers have been used on the North Atlantic aboard the CSS *Hudson* by Nortech, University of New Brunswick, and the Canadian Hydrographic Survey. Here a real time Kalman filter was used to combine GPS ranging and ships motion information to update an inertial navigational system. Further, STI's self-contained model 502B receivers provide *real time* positioning with precision on the order of 20 m with no postprocessing.

Paul D. Perreault
Technical Staff
Stanford Telecommunications, Inc
Santa Clara, CA 95050

Reply

I apologize to Dr. Perreault and Stanford Telecommunications, Inc., for my lack of precision in the subject article. A more proper statement would have been "The first receiver to become commercially available *for centimeter level surveying* is the Macrometer Model V-1000 Interferometric Surveyor, manufactured by Macrometrics, Inc., of Woburn, Massachusetts. We at the National Geodetic Survey are well aware of the important role played by STI in the development of the GPS system.

John D. Bossler
Director of Charting and Geodetic Services
NOAA
Rockville, MD 20852

Biography of Wiechert

For a biography I am writing of Emil Wiechert (1862–1928), professor of geophysics at the University of Gottingen, I would appreciate hearing from any readers who might have material of interest. Photos, letters, and anecdotes about his life are all welcome.

Wilfried Schroder
Hechelstrasse 8
D-2820 Bremen-Roennebeck
Federal Republic of Germany

Fig. 2. Arthur E. Maxwell *(right)* and James M. Snodgrass straightening the heat probe after one of its lowerings on the 1950 Midpac Expedition.

Scripps Institution of Oceanography

Article (cont. from p. 73)

1951]. *It is difficult to determine from the* detailed description of this instrument in that reference what modifications he and his laboratory may have made of the original design. Bullard obtained his first heat-probe measurements with the NPL-built instrument in July 1952 from R.R.S. *Discovery II* in the Atlantic.

Maurice Ewing, at the Lamont (now Lamont-Doherty) Geological Observatory, set out to measure heat flow after using a borrowed Bullard probe in 1953 that failed to work. By 1957 Robert Gerard and Ewing had developed a needle-probe device for measuring heat flow that was attached to the routinely used piston corer [*Gerard et al.*, 1962].

What was so exciting about those early ocean measurements of heat flow? As *Bullard* [1965] charmingly recounted in the historical introduction to Lee's book, *Terrestrial Heat Flow*, two committees of the British Association for the Advancement of Science, one in 1868 and one in 1935, had been appointed "to consider" underground temperatures and thermal conductivities in mines. Bullard conducted some of the experimental work for the 1935 committee, and, typically for whatever he was doing, he became intrigued by the breadth of the subject. What might be different about the deep ocean?

The state of the art was summarized in the *Bullard et al.* [1956] paper:

> ... there are only a few dozen reliable measurements of heat flow on the continents. The values range between 0.5 and 3 µcal/cm²sec ..., most of them being between 0.8 and 1.1. The mean is about 1.2 µcal/cm²sec.
>
> The continental heat flow is easily accounted for by the radioactivity of the continental rocks. ... Since a large part of the material above the Mohorovicic discontinuity at a depth of about 35 km must be granite or similar rocks, and since some heat must come from below the discontinuity, the difficulty is not so much to find a source for the observed heat as to explain why the flow is not greater than it is ...
>
> The petrological study of oceanic rocks and seismological work at sea have shown that the crust beneath the ocean basins is strikingly different from that underlying the continents ...
>
> In view of the striking differences in petrology and structure between the oceans and the continents it might be expected that the heat flowing from the oceans would be only a fraction of that from beneath the continents. In fact this is not so.
>
> Since the oceans cover 71% of the earth's surface, a reliable estimate of the amount of heat flowing through their floors is of great importance in discussions of the earth's thermal history. The oceanic measurements are not, however, merely an addition to the continental ones; in view of the fundamental differences between the oceans and the continents the heat flow at sea poses a problem separate from that of the continental heat flow.

Immediately after the Midpac Expedition, Revelle wrote to Bullard (October 15, 1950; carbon of letter in archives of the Scripps Institution's Marine Expeditions/Midpac):

> We managed to get at least seven good measurements of temperature gradients in the bottom muds. All but one of these indicate a gradient around 0.12°C per meter. If your conductivity estimates can be used, this means that the heat flow from the sea floor is the same as that from the continents. To me, at least, this is a very surprising result, but apparently you slyly suspected it all along.

Revelle and Maxwell [1952], in their letter in *Nature*, cited six measurements, with the comment: "It is noteworthy that at five of the six localities, covering a total distance of nearly three thousand miles, the computed heat flow lies within 20 per cent of the average value for the continents."

Bullard [1952], in the letter to *Nature*, said that the "communication by Revelle and Maxwell [from the Midpac Expedition] gives a result which is completely unexpected, and demonstrates again how little we know of submarine geology."

When Bullard first concerned himself with measuring the flow of heat through the ocean floor in 1939 and had the opportunity at Scripps Institution in 1949, the tectonic demarcation between land and sea to geologists was sharp. Every bit of evidence was needed to understand the whole earth. As measurements accumulated, patterns of variation in heat flow through the ocean floor began to emerge, and orders of magnitude for "average" values improved. *Langseth and Von Herzen* [1970, p. 299] noted that "a surface flux of up to eight times the earth's average is observed near the axis of the mid-oceanic ridges."

Those early heat-probe measurements, acquired with "a very clumsy apparatus" that began in Bullard's mind and hands, contributed considerably to the global knowledge of today's geophysicists.

References

Bullard, E. C., Heat flow in South Africa, *Proc. R. Soc. London Ser. A, 173*, 474–502, 1939.
Bullard, E. C., [Comment following letter by R. Revelle and A. E. Maxwell], *Nature, 170*, 200, 1952.
Bullard, E. C., The flow of heat through the floor of the Atlantic Ocean, *Proc. R. Soc. London Ser. A, 222*: 408–429, 1954.
Bullard, E. C., Historical introduction to terrestrial heat flow, in *Terrestrial Heat Flow, Geophys. Monogr. Ser.*, vol 8, edited by William H. K. Lee, pp 1–6, AGU, Washington, D. C., 1965.
Bullard, E. C., A. E. Maxwell, and R. Revelle, Heat flow through the deep sea floor, *Adv. Geophys., 3*, 153–181, 1956.
Gerard, R., M. G. Langseth, Jr., and M. Ewing, Thermal gradient measurements in the water and bottom sediment of the western Atlantic, *J. Geophys. Res., 67*, 785–803, 1962.
Langseth, M. G., Jr., and R. P. Von Herzen, Heat flow through the floor of the world oceans, in *The Sea*, vol. 4, edited by A. E. Maxwell, pp. 299–352, 1970.
Revelle, R., and A. E. Maxwell, Heat flow through the floor of the eastern North Pacific Ocean, *Nature, 170*: 199–200, 1952.

Edward C. Bullard 1907–1980

Professor Sir Edward Bullard was honored by his Queen in 1975 as a "world leader in geophysics." Each of those words is apt:

"world"—because indeed the earth was his domain, in theory and field work, in civilized and remote regions, and at sea;

"leader"—because after listening to and conversing with students and colleagues he edged them toward carrying out large ideas from half-formed thoughts;

"geophysics"—a field between precise physics and imprecise geology that came into being only because a few outstanding and versatile scientists like Bullard could span the breadth.

"Chance led me into geophysics at a wonderful time," he said, "and it has been among the most rewarding experiences of my life to have played a part in the transformation of a backwater into a bandwagon" [*Bullard*, 1975*b*].

Teddy Bullard carried this off with a unique charm, with a near-Puckish humor, and with an interest in people that made every chat with him memorable and every lecture by him a keen delight. His legacy will prove to be more than his own considerable scientific endeavors: it will include the accomplishments of his students and colleagues and a better effort even by his casual acquaintances. It has been said: "The thing looked so simple when Teddy explained it; it was only later you realized how deeply he understood" [*Matthews*, 1980].

He was an outgoing man, quite lacking in pomposity, yet very aware of status in his acquaintances. He observed the differences but never made invidious comparisons between his homeland and his adopted home country. Although he appeared disinterested in honors, one sensed that they pleased him.

Edward Crisp Bullard was born on September 21, 1907, in Norwich, England, where his father's family were brewers. In his early years he was not an outstanding student, but during high-school years he developed a keen interest in physics through a teacher. He entered Clare College, Cambridge, and graduated with first-class honors in physics. In 1929 he became a graduate student in the Cavendish Laboratory of Lord Rutherford, from which he received his Ph.D. in 1932 with a dissertation on the scattering of slow electrons in gases.

The first position available to the young physicist in those depression years was for the Department of Geodesy and Geophysics at Cambridge, as a demonstrator in surveying. As such, according to Bullard (who wrote a tribute to himself at the request of Walter Munk), he "embarked on a very profitable eight years in which he learned the elements of Earth science and carried out a remarkably diverse series of projects. The success of these was in large part due to the steady support of [Colonel Sir Gerald] Lenox-Conyngham, who was not at all disturbed when told that the police were looking for the perpetrators of an explosion which had left a hole in a road in Leicestershire" [*Munk*, 1978].

The first in the diverse series of projects was measuring small variations in gravity, for which Bullard developed an elegant technique for timing the swings of an invariant pendulum. The work was done during 1933–1934 in the East African Rift Valley, where on one occasion he and his wife Margaret were treed by a lion.

The explosion that disturbed the police was part of a group program to map the Paleozoic layer beneath eastern England by means of seismic refraction. At the 1936 meeting of the International Union of Geodesy and Geophysics in Edinburgh, Bullard met Princeton geologist Richard M. Field. It was Field's insistent theme that geologists must study the ocean floor. *Bullard* [1975*a*] said: "He would not take no for an answer, he would not stop talking, he had no doubts, he was embarrassing and sometimes a nuisance, and yet he struck the match that set earth science alight. . . . He invited me to the United States in 1937 . . . and sent me out to sea with the Coast and Geodetic Survey and with Maurice Ewing." Upon his return to England, Bullard began seismic studies with Thomas F. Gaskell in the western approaches to the English Channel aboard two Brixham sailing trawlers.

As a third venture into the young field of geophysics, Bullard measured the temperature gradient, or heat flow, on land in England and in South Africa in 1938–1939. This was for a committee of the British Association for the Advancement of Science, appointed in 1935. Work of this kind, said Bullard once, "had been done extraordinarily badly before" [*Shor*, 1984], and elsewhere he noted: "Great difficulty was experienced in finding suitable [bore]holes, but very satisfactory results were obtained from those that were found" [*Bullard*, 1965]. The project led Bullard to pondering a means of measuring heat flow in the deep ocean.

On the advent of World War II, Bullard became an Experimental Officer in the Naval Scientific Service, first to develop methods for protecting ships from magnetic mines, then to develop methods for sweeping acoustic and magnetic mines. He moved on to intelligence investigations pertaining to the German development of rockets and to a study of the most economical ways of attacking firing sites in France. The *Times* noted that Bullard "built up around him an astonishingly versatile and effective establishment which, in the urgency of time, had when necessary, an utter disregard for the formalities of normal civil service rules, and thus moved with a speed impossible for other establishments" [*Matthews*, 1980]. His participation in matters for the Ministry of Defence continued for many years, and he served on the committee for a nuclear-test ban treaty also.

Bullard returned to Cambridge in 1945, where he found the laboratory in a shambles after 6 years of disuse, but he got it into operation and soon became head of the Department of Geophysics. The lack of research funds and lack of access to a research ship frustrated him to the extent that in 1948 he accepted the position as head of the Physics Department at the University of Toronto in Canada. There he initiated theoretical inquiries into the source of the earth's magnetic field, using the early computer system ACE. Bullard's long-pursued work on dynamo theory of the earth's core constitutes his most profound single contribution to knowledge of the earth.

In 1950 Bullard returned to England to succeed Sir Charles Darwin [grandson of the author of *The Origin of Species*] as Director of the National Physical Laboratory at Teddington. While chafing some at the responsibilities, he felt that he was an effective director, and he was able to do a substantial amount of his own researches. In fact, "through his position as director he was able to deploy the entire resources (by no means inconsiderable) of the computing division to carry out extensive numerical work required for the development of his [dynamo] theory" [*Massey*, 1980]. The position and his competence gained him a knighthood in 1953.

Bullard in 1956 resolved his indecision about what kind of life he wanted by returning to Cambridge, again as head of the Department of Geodesy and Geophysics. There he felt that his primary commitment was to his own work and to helping a large number of very able graduate students. It was an era of ferment in the expanding field of geophysics, and Cambridge became a focal point. In 1963, for instance, Harry Hess, J. Tuzo Wilson, Drummond Matthews, and Fred Vine were all at Cambridge, and Bullard was reassembling the continents by computer with deceptive simplicity [*Bullard*, 1964]. Seafloor spreading and plate tectonics were launched, and for those theories Teddy Bullard was a primary catalyst.

In his Cambridge years he also directed a major investigation into electromagnetic induction in the earth; he helped in establishing the technique of determining the age of rocks by the potassium-argon method; and he encouraged the application of modern computer techniques to geophysical problems. Always he was interested in the history of science, and he assembled a considerable library in it. This seemed to be an outgrowth of his interest in people: for an individual's memorial account he wanted to know not only the science but also the minutest details of that person's life. He quite enjoyed writing historical summaries of aspects of geophysics.

Bullard's association with Scripps Institution of Oceanography in La Jolla, California, began with a brief visit in 1948, followed by a 2-month stay in 1949 when his first heat-probe was developed [Shor, 1984]. From the mid-1950's he was a frequent visitor to Scripps, where from 1963 to 1977 he held a part-time appointment as professor of geophysics. When he retired from Cambridge in 1974, he moved to La Jolla permanently. There he continued to work vigorously on what he called "his favorite topics of plate tectonics and the origin of the Earth's magnetic field," and he was drawn into an advisory role to the U.S. government on nuclear-waste disposal. In all, he published some 200 papers (a memorial account and a complete bibliography will be published by the Royal Society of London).

Bullard married Margaret Ellen Thomas in 1931; they had four daughters. Margaret was the author of several novels situated in various places where the family had lived. In 1974, Bullard married Ursula Margery Curnow of New Zealand; she is an accomplished painter and sculptor.

This giant in geophysics died of cancer on April 3, 1980, in La Jolla. Only a few hours before his death he approved final changes on the paper "Direction of the earth's magnetic field in London, 1570–1975," with Stuart Malin of Edinburgh. Teddy made life interesting, and he faced death with courage.

At the change of command in 1976, the Albatross Award of the American Miscellaneous Society was transferred to Edward C. Bullard *(right)* from Roger Revelle *(left)*. It's a scruffy bird, but a signal honor.

Awards to Edward C. Bullard

Sedgwick Prize, 1936
Fellow, Royal Society of London, 1941
Hughes Medal, Royalty Society of London, 1953
Foreign Honorary member, American Academy of Arts and Sciences, 1954
Chree Medal, Physics Society, 1956
Foreign Associate, National Academy of Sciences, 1959
Day Medal, Geological Society of America, 1959
Gold Medal, Royal Astronomical Society, 1965
Agassiz Medal, National Academy of Sciences, 1965
Wollaston Medal, Geological Society of London, 1967
Vetlesen Medal and Prize, Columbia University, 1968
Royal Medal, Royal Society of London, 1975
Bowie Medal, American Geophysical Union, 1975
Albatross Award, American Miscellaneous Society, 1976
Maurice Ewing Medal, American Geophysical Union, 1978

The facilities of the Cambridge Department of Geodesy and Geophysics were named the Bullard Laboratories in 1980.

References

Bullard, E. C., Continental drift, *J. Geol. Soc. London, 120*, 1–33, 1964.
Bullard, E. C., Historical introduction to terrestrial heat flow, in *Terrestrial Heat Flow, Geophys. Monogr. Ser.*, vol. 8, edited by William H. K. Lee, pp. 1–6, AGU, Washington, D. C., 1965.
Bullard, E. C., The emergence of plate tectonics; a personal view, *Annu. Rev. Earth Planet Sci., 3*, 1–30, 1975*a*.
Bullard E. C., Acceptance of the William Bowie Medal, *Eos Trans. AGU, 56*, 919, 1975*b*.
Massey, H. S. W., Sir Edward Bullard, *Phys. Today*, p. 67, August 1980.
Matthews, D., Sir Edward Bullard: An outstanding scientist of his time, *The Times*, London, April 5, 1980.
Munk, H., Dedication to topics in nonlinear dynamics: A tribute to Sir Edward Bullard [written by Bullard at Munk's request], *AIP Conf. Proc., 46*, v-viii, 1978.
Shor, N., E. C. Bullard's first heat-probe, *Eos Trans. AGU, 65*, this issue, 1984.

This tribute was contributed by Elizabeth N. Shor, *La Jolla, CA 92037.*

EOS

Transactions, American Geophysical Union

The Weekly Newspaper of Geophysics

For speediest treatment of contributions send three copies of the double-spaced manuscript to one of the editors named below and one copy to AGU.

Editor-in-Chief: A. F. Spilhaus, Jr.; **Editors:** Marcel Ackerman, Mary P. Anderson, Peter M. Bell (News), Bruce Doe, C. Stewart Gillmor (History), Clyde C. Goad, Arnold L. Gordon, Louis J. Lanzerotti, Robert A. Phinney; **Managing Editor:** Gregg Forte; **News Writer:** Barbara T. Richman; **News Assistant:** Tony Reichhardt; **Production Staff:** James M. Hebblethwaite, Dae Sung Kim, Patricia Lichiello, Lisa Lichtenstein, Cynthia T. McManigal.

Subscription price to members is included in annual dues ($20 per year). Information on institutional subscriptions is available on request. Second-class postage paid at Washington, D. C., and at additional mailing offices. *Eos, Transactions, American Geophysical Union* (ISSN 0096-3941) is published weekly by

American Geophysical Union
2000 Florida Avenue, N.W.
Washington, DC 20009

Cover. This weak-beam micrograph shows a twist boundary in an experimentally deformed olivine single crystal from San Carlos (Arizona). It was taken with a 125 KeV transmission electron microscope. The scale bar is 2200 nm. Such orthogonal arrays of screw dislocations are also commonly observed in naturally deformed peridotites. They are produced during deformation or annealing events either in the earth's mantle or during the ascent of the olivine-bearing bodies to the surface. The micrograph was taken by Daniel L. Ricoult (advisor: D.L. Kohlstedt), Department of Materials Science and Engineering, Cornell University, Ithaca, New York.

An Invitation

Would you like to be on the cover of *Eos*? If you have any illustrations with both aesthetic charm and scientific interest—photographs (preferably black and white) of geophysical phenomena, experimental results, or graphs—*Eos* would like to consider them for publication on the cover. Send the original illustration or 8 x 10 inch (20 x 25 cm) glossy photo with a short (50–200 words) explanation that can serve as a caption. You may also submit a more extensive news item or even a short article to accompany a proposed cover. Captions will be by-lined. If the material has been previously published, please supply a copyright release from the copyright owner. Send it to *Eos* Cover, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

News

Cretaceous Boundary

Four years after it was first proposed, the theory that a colossal meteorite struck the earth 65 million years ago continues to build toward a consensus—this despite recent findings that volcanic eruptions might also have caused the "iridium anomaly" that is the impact theory's best evidence (*Eos*, February 7, 1984, p. 41).

High concentrations of iridium at the Cretaceous-Tertiary boundary were first noticed in sediments from Italy, Denmark, Spain, and other locations around the world by Walter Alvarez, his father Luis, and their Berkeley colleagues. They concluded that the source of the extra iridium must have been extra-terrestrial because the element shows up in crustal rocks only in very small amounts and no one could think of a mechanism that would distribute iridium from the mantle so widely around the surface of the globe. The Alvarez group postulated that a meteorite about 10-km wide had collided with the earth, throwing up a planet-encircling cloud that blocked out sunlight, ended photosynthesis, and snuffed out many of the land and sea creatures of the Mesozoic, including the dinosaurs.

Until recently, the iridium anomaly was virtually the only support for this idea. In November, however, two researchers from Yale University, Jean-Marc Luck and Karl Turekian, reported what may be even more compelling evidence. They analyzed osmium isotopes in boundary-layer rocks from Denmark and Colorado—osmium is another platinum-group metal that shows up anomalously high in these sediments—and found nearly equal amounts of ^{187}Os and ^{186}Os, an isotopic ratio much more characteristic of meteorites than of crustal rocks. Luck and Turekian had first hypothesized that if a normal geochemical process such as precipitation from seawater had concentrated the osmium, they would see the higher ratio found in terrestrial rocks. After examining a number of oceanic manganese nodules, they found that this was indeed the case, and so concluded that it was a meteorite impact (or possibly two impacts, since they found different ratios at the two sites) that deposited the osmium.

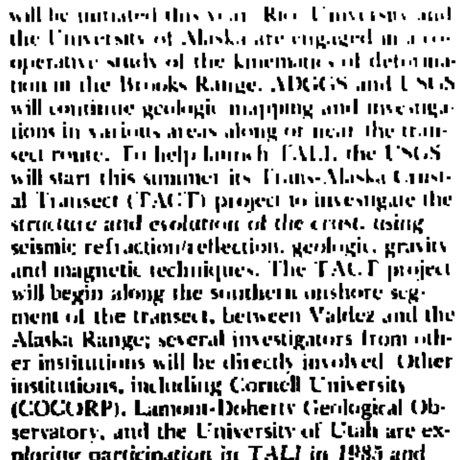
With this new information, is there now a consensus on the meteorite theory? Not yet, says Charles Orth of the Los Alamos National Laboratory, who provided Luck and Turekian with the sample from Colorado's Raton Basin and who was the first to find the iridium anomaly in freshwater sediments. "We can't yet lay to rest a volcanic source—we need to learn more about the platinum metal ratios in the mantle." Recent findings at Kilauea in Hawaii show that iridium can be concentrated on the surface after settling out from volcanic emissions. It would have required an enormous explosion to distribute this volcanic material globally in the Cretaceous-Tertiary boundary layer, however, and the sort of slow, oozing flows that normally accompany eruptions like Kilauea are not consistent with this.

Most frustrating of all for the meteorite-theory faithful is the continuing lack of any evidence of an impact. So far, about 100 craters around the world have been evaluated as possible candidates, according to Thomas J. Ahrens of the California Insitute of Technology, "but none seem to be the right size and age." For this reason, many people favored the idea of an ocean impact right from the start. After all, Ahrens points out, the climate was warmer 65 million years ago, water wasn't locked up in polar ice caps, and there was more ocean.

An ocean impact would also explain why no crater has been identified—more than half the ocean floor that existed 65 million years ago is gone, subducted back into the mantle. Furthermore, recent reports of small spheroids that appear to be altered "impact droplets" of basaltic origin (found in boundary layer clays in northern Italy and the central Pacific by Alessandro Montanari and colleagues at Berkeley) make the case for a seafloor impact even stronger. But where are the remnants of the great tsunamis and submarine landslides that would have followed such an event? No one has yet come up with a good answer.

Meanwhile, Charles Orth and others are looking for iridium anomalies at other periods in geologic history. This leads to another question: If meteorites do occasionally hit the earth, are they responsible for mass extinctions? Orth and various coinvestigators have checked for high iridium concentrations in clays known to be deposited during other periods of wholesale extinctions, including two trilobite-brachiopod boundaries in the late Cambrian, where they found no iridium anomaly. Orth has also checked boundary layers from the Ordovician-Silurian and the late Devonian. No anomalies there, either. But he continues to search for other examples of iridium excess across time and plans to widen the geographic range of his studies of the Cretaceous-Tertiary boundary layer to establish a more global pattern.

Walter Alvarez, with whom it all started, will have a paper in *Science* next month in which he counters the counterargument that the extinctions at the end of the Mesozoic were gradual and so couldn't have been caused by one catastrophic event. Alvarez and his coauthors, based on a review of the existing paleontological literature, see "a sharp dropoff" right at the iridium-rich boundary layer for four groups of marine invertebrates: ammonites, one group of bryozoans, brachiopods, and bivalves. "Some paleontologists have said that the dropoffs were more gradual," Alvarez told *Eos*, "but we looked back at the record, rather than what they say the record shows."—*TR*



Planetary Science Budget

The fiscal year 1985 budget for the solar system exploration program of the National Aeronautics and Space Administration (NASA) is very promising (*Eos*, February 14, 1984, p. 49). As announced by the Office of Management and Budget, the document includes a new start-up program for the MGCO (Mars Geoscience Climatology Orbiter) mission. Mixed in with the set of encouraging figures of NASA's Space Science and Applications budget plan, unfortunately, is the more uncertain area of funding that includes support for the Research and Analysis program. These programs seem to be less visible in the budget, but they include important components of the space science program. A large portion of these funds is provided to university scientists to support research at the highest levels of excellence.

In a recent letter to members of the academic scientific community, William L. Quaide, chief scientist of NASA's Solar System Exploration Division, expressed a note of uncertainty and caution about the fiscal year 1985 budget operating leel for the Research and Analysis programs. According to Quaide: "The reduction in [Research and Analysis] funds will require that we abandon, temporarily, plans to address all the problems that are facing us, and concentrate our support on a few specific areas to preserve somecontinuity of participation and to maintain conpabilities for future missions."

Quaide pointed out that an augmentation of $15 million will be needed to maintain the support level of funding realized by the fiscal 1984 appropriation. Indeed, an augmentation for the research and analysis program is included in the president's budget, but only in the amount of $6 million. Conceivably that number could be increased by Congress if the need were made known.—*PMB*

Titan Ocean: Ethane, Methane, Nitrogen

Detection of the atmosphere of Saturn's satellite Titan by the Voyager I spacecraft indicated an abundance of only 3 mol % methane (CH_4). Recently J. I. Lunine, D. J. Stevenson, and Y. L. Yung calculated that 3 mol % methane is sufficiently low to preclude the stable coexistence of liquid methane on Titan's surface, which has a temperature of 94 K (*Science, 222*, 1229, 1983). Instead, Lunine et al. suggest that Titan's atmospheric methane may have broken down by a catalyzed photochemical reaction to ethane (C_2H_6). The resulting ocean would consist of a mixture of C_2H_6 and CH_4 in the proportion of 3 to 1.

The dissociation steps of C_2H_6 involve loss of hydrogen by escape, making the process irreversible. The postulated set reactions are: $2CH_4 \rightarrow C_2H_6 + H_2$ and $2CH_4 \rightarrow C_2H_6 + 2H$. The intermediate molecule C_2H_2 plays the role of catalysis and shielding of C_2H_6 from photolysis. CH_4 is calculated as being broken down in Titan's atmosphere at a rate of 1.5×10^{10} cm^{-2} s^{-1}. The evolved H and H_2 would leave the exosphere at rates of 5.5×10^9 and 7.2×10^9 cm^{-2} S^{-1} respectively. The result is the production of an ethane-rich ocean of 1 km depth. The composition of Titan's present ocean was deduced from calculations of the C_2H_6–CH_4, N_2–CH_4, and N_2–C_2H_6 binary systems. To be consistent with Voyager observations, it was noted that the existence of several percent propane in the ocean would be compatible with the calculated proportions. The calculations also include a 100–200 km thick layer of solid C_2H_2 on Titan's ocean floor.

What is lacking to make a case for an ethane-rich ocean is more observational data. Lunine et al. note that important tests of the model are verification of the existence of CH_4 clouds with the correct opacity, detection of C_2H_6 saturation of the lower troposphere, and radar evidence of an ocean.—*PMB*

Alaskan Transect

A cooperative geophysical/geologic transect of the Alaskan crust and upper mantle is being organized by the U.S. Geological Survey (USGS), the Alaska Division of Geological and Geophysical Surveys (ADGGS), the University of Alaska, and Rice University. The project is to be known as the Trans-Alaska Lithosphere Investigation (TALI). The route of TALI lies along the north-south corridor of the trans-Alaska oil pipeline between Prudhoe Bay and Valdez and extends offshore across the Pacific and Arctic continental margins. The transect will incorporate several supplementary profiles intersecting the primary route. TALI is envisaged as a coordinated multidisciplinary effort among government, academic and industry scientists and institutions.

To prepare a prospectus for the transect, a workshop will be held in Anchorage on May 29 prior to the meeting of the Seismological Society of America and the Cordilleran Section of the Geological Society of America (May 30–June 1). The National Science Foundation is co-sponsoring the workshop.

Some of the studies that will constitute important elements of TALI are under way or will be initiated this year. Rice University and the University of Alaska are engaged in a cooperative study of the kinematics of deformation in the Brooks Range. ADGGS and USGS will continue geologic mapping and investigations in various areas along or near the transect route. To help launch TALI, the USGS will start this summer its Trans-Alaska Crustal Transect (TACT) project to investigate the structure and evolution of the crust, using seismic refraction/reflection, geologic, gravity and magnetic techniques. The TACT project will begin along the southern onshore segment of the transect, between Valdez and the Alaska Range; several investigators from other institutions will be directly involved. Other institutions, including Cornell University (COCORP), Lamont-Doherty Geological Observatory, and the University of Utah are exploring participation in TALI in 1985 and later years. The goal is to complete the transect by the end of thisdecade.

Geologists and geophysicists interested in participating in TALI or the May workshop should contact: Robert Page, U.S. Geological Survey, Mail Stop 77, 345 Middlefield Rd., Menlo Park, CA 94025 (415-323-8111); or John Davies, Alaska Division of Geological and Geophysical Surveys (907-474-6166), or David Stone, University of Alaska (907-474-7622), both at the Geophysical Institute, University of Alaska, Fairbanks, AK 99701.

This news item was contributed by Robert A. Page, *who is with the U.S. Geological Survey, Menlo Park, CA 94025*

Geophysicists

Two AGU members received Fulbright scholarships for 1983–1984: ***John R. Holloway***, professor of chemistry at Arizona State University, will be working in Australia. ***Teh-Lung Ku***, professor of geological sciences at the University of Southern California, will be working in France.

In Memoriam

The following AGU members are recently deceased. Their AGU section affiliation and year of joining AGU are shown.

Jaime Amorocho, 64. An AGU Fellow, Hydrology, joined 1952.

Grover B. Crisp, 43, on April 20, 1983. Geodesy, joined 1980.

Mahdi Salih Hantush, 63, on January 14, 1984. Hydrology, joined 1949.

Allen A. Jergins, 80. Seismology, joined 1943.

Jack H. Meek, 66, on October 12, 1983. Solar-Planetary Relationships, joined 1959.

Heinz G. Poetaschke, 68, in November 1983. Geodesy, joined 1976.

Books

The Boundary Integral Equation Method for Porous Media Flow

James A. Liggett and Phillip L.-F. Liu, Allen and Unwin, New York, 1983, xi + 255 pp. $35.

Reviewed by Mary P. Anderson

Just as groundwater hydrologists are breathing sighs of relief after the exertions of learning the finite element method, a new technique has reared its nodes—the boundary integral equation method (BIEM) or the boundary equation method (BEM), as it is sometimes called. As Liggett and Liu put it in the preface to *The Boundary Integral Equation Method for Porous Media Flow*, "Lately, the Boundary Integral Equation Method (BIEM) has emerged as a contender in the computation Derby." In fact, in July 1984, the 6th International Conference on Boundary Element Methods in Engineering will be held aboard the *Queen Elizabeth II*, en route from Southampton to New York. These conferences are sponsored by the Department of Civil Engineering at Southampton College (UK), whose members are proponents of BIEM. The conferences have featured papers on applications of BIEM to all aspects of engineering, including flow through porous media. Published proceedings are available, as are textbooks on application of BIEM to engineering problems. There is even a 10-minute film on the subject.

The applications of BIEM to flow through porous media are explored by the other major proponents of this method in this textbook by Liggett and Liu of Cornell University. Briefly, BIEM involves an application of Green's formula, which allows the dimensionality of a problem to be reduced. The method consists of placing nodes on the boundaries of the domain—a line for 2-dimensional problems, an area for 3-dimensional problems—and integrating over the boundary. Then application of Green's formula makes it possible to solve for the head at any point in the interior of the domain. The catch is that it is necessary to know both heads and their normal derivatives along the boundary. Fortunately it is possible to derive an expression relating head along the boundary to its normal derivative, so that given either head or its derivative, it will be possible to solve for the other at each node. An advantage of the method is that any approximation involved in discretization is limited to the boundary, although there is a boundary layer effect causing heads near the boundary to be more subject to numerical errors than heads in the interior of the domain. Liggett and Liu suggest that the thickness of this boundary layer is approximately equal to the length of a boundary element.

The book is written at an advanced level and requires a thorough familiarity with calculus as well as the theory of flow through porous media and finite element techniques. The examples used to illustrate the use of the BIEM reflect the training of the authors, in that classical engineering problems in flow through porous media are emphasized including flow through dams, flow around a cut-off wall, flow to wells, seepage from a pond, and recharge from circular and rectangular regions.

A mathematically compact introductory chapter reviews the basic theory of flow through porous media and the relevant governing equations and serves to introduce the reader to the authors' notation. Chapter 2 describes the application of the method to simple problems involving Laplace's equation and linear interpolation of head between boundary nodes (linear boundary elements). Chapter 3 deals with more sophisticated interpolation schemes, known as special elements. Chapter 3 also introduces a powerful feature of the method, whereby infinite domains can be treated by using an analytical solution to construct a special element to extend the problem domain from the near-field solution, where a detailed solution is desired, out to infinity. In this way the problem of defining nearfield boundary conditions is avoided.

BIEM treats heterogeneity by dividing the problem domain into several homogeneous zones. The concept of zones and the equation manipulation (by stretching the coordinate system) required to treat anisotropy are discussed in Chapter 4. Chapter 5 describes the solution of transient free-surface problems using steady state governing equations and transient boundary conditions on the free surface. Chapter 6 deals with axial symmetric flow problems, including recharge from circular areas and flow to wells. Chapter 7 deals with 3-dimensional solutions of Laplace's equation applied to well problems and to unconfined aquifers using a transient boundary condition on the free surface. Chapter 8 discusses the application of BIEM to problems involving a sharp interface between two fluids, e.g., salt water intrusion without dispersion. Chapter 9 focuses on the intriguing way in which boundary elements can be combined with standard finite elements. It is clear that a finite element approximation is more appropriate for heterogeneous problems. However, if only a portion of the problem domain is heterogeneous, it may be advantageous to use boundary elements for the nonheterogeneous portion. Examples presented in chapter 9 include unsaturated-saturated problems, in which finite elements are used for the unsaturated zone and boundary elements are used for a homogeneous saturated zone. Throughout chapters 2–9, the results of the BIEM are compared to analytical solutions and to results of finite difference and finite element solutions drawn from the literature.

Chapter 10, the longest in the book, discusses the application of BIEM to problems involving regional groundwater basins including leaky aquifers. The problems are handled using a quasi 3-dimensional approach, whereby flow through aquifers is assumed to be horizontal and flow through confining beds is assumed to be vertical. Reference is made to a computer code called GM5, which was used to simulate the Yun-Lin aquifer in Taiwan. Output from the simulation is presented but the code is not, owing to space limitations. However, sample FORTRAN codes are presented in chapter 11. The code GM8 solves the Laplace equation using linear elements; GM9 is an extension of GM8 that allows for the use of special elements; and the program DAM solves transient free surface flow through a dam of constant hydraulic conductivity. In addition to the codes, documentation of input as well as sample input and output data sets are presented. An appendix containing a list of symbols used in the book and discussion of some of the finer mathematical points is also provided.

The authors succeed in presenting a convincing case for the utility of BIEM for certain types of engineering problems in flow through porous media. Yet the book's bibliography gives only a few references on applications of BIEM to flow through porous media and these are largely papers by Liggett or Liu. Hence, one is left wondering why the method seemingly has not caught on among specialists. The arsenal of mathematics needed to understand and program BIEM rivals the finite element method, and as a result BIEM is unlikely to take hold among "the masses" until the documentation and release of general "canned" programs similar to the one discussed in chapter 10. Still, the book is a good start in bringing BIEM to the attention of groundwater hydrologists and will be especially useful to those who already have a working knowledge of finite elements and who have occasion to solve those classes of problems for which BIEM is particularly suited.

Mary P. Anderson is with the Department of Geology and Geophysics at the University of Wisconsin–Madison, Madison, WI 53706.

Electronic Mail

You can now communicate with AGU headquarters via telemail. The following individuals can be reached directly on Telenet:

	MAILBOX
Fred Spilhaus, Executive Director	FSPILHAUS/AGU
Cynthia Bravo, Director of Meetings and Member Programs	CBRAVO/AGU
Judy C. Holoviak, Director of Publications, Public Information, and Marketing	JHOLOVIAK/AGU
Michael Connolly, Publications Coordinator	MCONNOLLY/AGU
Edward Patrick, Publications Coordinator	RPATRICK/AGU

Classified

RATES PER LINE

Positions Available, Services, Supplies, Courses, and Announcements: first insertion $5.00, additional insertions $4.25.

Positions Wanted: first insertion $2.00, additional insertions $1.50.

Student Opportunities: first insertion free, additional insertions $2.00.

There are no discounts or commissions on classified ads. Any type style that is not publisher's choice is charged at general advertising rates. *Eos* is published weekly on Tuesday. Ads must be received in writing by Monday, 1 week prior to the date of publication.

Replies to ads with box numbers should be addressed to Box ___, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, DC 20009.

For more information, call **202-462-6903 or toll free 800-424-2488.**

POSITIONS AVAILABLE

Program Manager-Air-Sea Interaction. NASA Headquarters' Oceanic Processes Branch is seeking candidates for planning, developing and implementing a scientific research program utilizing satellite techniques in the general area of air-sea interaction. Specifically included is the use of satellite scatterometry to characterize the surface wind field, and the effect of surface winds on upper-ocean currents. Qualifications include 1) ability to communicate effectively, 2) demonstrated experience in conducting original research, 3) program management experience, and 4) knowledge of physical oceanography. GS 14/15, with salary range from $41,277 to $63,115, commensurate with experience/education. For further information regarding requirements and application procedures write to address below or phone 202-755-0987. Formal applications must be received by March 6, 1984.
NASA Headquarters, Code NBP, Washington, DC 20546.
An equal opportunity employer.

Faculty Position/UCLA. The Department of Earth and Space Sciences, UCLA, seeks applications for a regular faculty position in the area of sedimentology, sedimentary petrology, basin analysis, stratigraphy, and regional geology. A Ph.D. or equivalent is required. There is no restriction as to the level. Duties will include undergraduate and graduate teaching, supervision of theses and dissertations, and development of a research program in the area of specialization. Field-based experience will be taken into consideration. The appointment will begin not later than January 1, 1985, and may begin as soon as July 1, 1984. It will be full-time, nine-month, tenure or tenure track. Send resume to: Dr. William M. Kaula, Chairman, Department of Earth and Space Sciences, University of California, 405 Hilgard Avenue, Los Angeles, CA 90024.
UCLA is an affirmative action/equal opportunity employer.

University of Colorado-Boulder—Tenure Track Position in Atmospheric Dynamics. The Department of Astrophysical, Planetary and Atmospheric Sciences (formerly Astro-Geophysics) invites applications for a tenure-track faculty position in the field of atmospheric science. The successful applicant must have a Ph.D. degree and should possess a strong background in geophysical fluid dynamics or dynamic meteorology, preferably in modeling large-scale terrestrial and/or planetary circulations. The appointment will be at the assistant professor level (although the associate professor level is not ruled out) and will begin August 29, 1984.

Applicants should have a strong commitment to research and to teaching at the graduate and undergraduate level. The opportunity will exist for a formal association with the Laboratory for Atmospheric and Space Physics, which has ongoing programs of space observations of planetary atmospheres.

To apply, please send a curriculum vita and the names and addresses of three references to:

Professor Gary E. Thomas
Department of Astrophysical, Planetary and Atmospheric Sciences
Campus Box 391
University of Colorado
Boulder, CO 80309
Telephone: 303-492-8913.

Salary: $21,000 minimum.

Application deadline: Postmarked no later than March 15, 1984. (Later applications will be accepted if the position is not filled)

The University of Colorado is an equal opportunity/affirmative action employer.

Planetary Geologist/Geophysicist: Jet Propulsion Laboratory, Earth & Space Sciences Division. The Planetary and Oceanography Section anticipates the availability of one or two fulltime, staff scientist research positions in the areas of planetary geology and geophysics. The rank of appointment is open, but applicants should be beyond the postdoctoral level with a demonstrated record of expertise and accomplishments in independent research and publication. We welcome applicants with interest in structural geology and geophysics as applied to the study of solid-body planets and natural satellites with emphasis on determining surface properties and processes on planetary objects using ground-base and spacecraft remote sensing data and applicable theoretical and experimental techniques. Applicants should send letter outlining their experience, professional goals, resume, and copies of pertinent publications to: Dr. William R. Ward, Manager, Planetology and Oceanography Section, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Dept 134, Mail Stop 249-104, Pasadena, CA 91109.
An equal opportunity employer m/f.

Postdoctoral Position/Dalhousie University. A two-year position in the Oceanography Department is available for a person interested in marine geophysics. Specific work involves participation in heat flow studies across the margins of eastern Canada but broader opportunities also exist for self-motivated projects within the University or at Bedford Institute of Oceanography. A Ph.D. in geophysics and desire to work 1-2 mos/yr at sea are required. Experience with heat flow helpful but not essential. Send C.V. and names of two references to: Dr. K. E. Louden, Dept. of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4J1.

Research Position in Space Plasma and Auroral Physics. Two research positions at the level of assistant or associate research scientists are available in the Department of Physics & Astronomy at the University of Iowa for qualified candidates with a Ph.D. degree and experience in space plasmas and/or auroral physics. Present research in space plasma physics emphasizes analysis and interpretation of observations of magnetospheric plasmas using instrumentation on board earth-orbiting spacecraft in the IMP and ISEE Missions. The University of Iowa's global imaging instrumentation on the spacecraft Dynamics Explorer 1 is the source of an extensive data base of auroral images from high altitudes at visible and ultraviolet wavelengths. Photometric observations are also available for other areas of research including the physics of the upper atmosphere and the global distribution of atmospheric ozone. The applicant should identify and describe areas of his or her expertise which can support experimental or theoretical investigations in space plasma physics and/or auroral physics. Salary and position will be determined by the applicant's qualifications and experience.

A resume and the names of three persons knowledgeable of applicant's experience should be forwarded to: L. A. Frank, Department of Physics & Astronomy, University of Iowa, Van Allen Hall, Iowa City, Iowa 52242.

The University of Iowa is an affirmative action/equal opportunity employer.

Geophysicist/University of Minnesota. The Department of Geology & Geophysics invites applications for a tenure track position in solid-earth geophysics beginning fall 1984. We seek a Ph.D. and preferably some postdoctoral experience. The field of interest is open but includes, for example, gravity/magnetics, global and regional tectonics and the physical state of the crust and mantle.

Present research programs in geophysics include geomagnetism and paleomagnetism, mineral physics at high pressures, and crustal seismology. We also emphasize the interconnectedness of geophysics with the in-house strong programs in auqueous and isotopic geochemistry, tectonics, and limnology.

Please submit a letter of application and attach a curriculum vitae, statement of research and teaching interests, a list of publications and the names of three to five references by March 15, 1984 to: Subir Banerjee, Department of Geology and Geophysics, 310 Pillsbury Drive, S.E., University of Minnesota, Minneapolis, MN 55455.

The University of Minnesota is an equal employment opportunity/affirmative action employer and encourages applications from qualified women and minorities.

Environmental Sciences Director. Growth opportunity to manage a division dedicated to environmental studies, technology development and mitigation, emphasizing innovative fossil energy recovery. Required is a PhD or equivalent plus 10 years related research and leadership/management accomplishment. Location in Rocky Mountains on University of Wyoming campus offers excellent quality of life for the outdoor recreation, university, small community oriented. Send credentials, including salary requirements to Manager of Personnel Services, WESTERN RESEARCH INSTITUTE, P.O. Box 3395, University Station, Laramie, WY 82071.
WRI is an equal opportunity employer.

Symposium on Meteorology and Oceanography of North America High Latitudes. A Symposium on Meteorology and Oceanography of Northern High Latitudes will be held October 3–5, 1984, in Anchorage, Alaska. The meeting will be cosponsored by the American Meteorological Society and the AAAS, and will be held in conjunction with the Alaskan Science Conference.

Papers are solicited on all aspects of high latitude meteorology and oceanography, although the focus will be on time scales ranging from less than a day to several months. Sessions are planned on the following topics: air-sea-ice interaction in the high latitudes of the North Pacific; longrange forecasting for the Alaskan region; meteorological aspects of air pollution in the Far North, with special emphasis on the Fairbanks region; and the variability and predictability of sea ice conditions in Alaskan waters. Papers describing results from the Bering Sea MIZEX (Marginal Ice Zone Experiment) are encouraged.

Abstracts of less than 200 words should be submitted by 1 April 1984 to Stuart Bigler, National Weather Service, 701 C Street, P.O. Box 23, Anchorage, Alaska 99513. Authors will be notified of acceptance of papers in early May.

University of South Alabama. Faculty Position. Tenure-track position at the rank of Assistant Professor in one of the two following fields: (1) Invertebrate Paleontology-Stratigraphy; (2) Igneous OR Metamorphic Petrology. The University of South Alabama has approximately 10,000 students, and is located in a growing metropolitan area. The Department of Geology and Geography has approximately 200 majors, and a faculty of nine full-time and three part-time members. This position is to be filled commencing September, 1984. The deadline for applications is May 15, 1984. Please submit letter of application, along with a resume of your education and experience, to: Dr. Glenn R. Sebastian, Chairperson, Department of Geology and Geography, University of South Alabama, Mobile, AL 36688. Also arrange to have at least three letters of reference sent to the same address.

The University of South Alabama is an equal opportunity, affirmative action employer.

Cosmochemistry Faculty Position/University of Arizona. The Department of Planetary Sciences and the Lunar and Planetary Laboratory invite applications for a state funded, tenure track position in Cosmochemistry. The area of specialization within Cosmochemistry is open. The appointment involves research, teaching, and the supervision of graduate students. The successful candidate will be either at a junior level with extraordinary promise of scientific accomplishment, as well as the potential for developing substantial leadership capabilities and an international scientific reputation, or will be at a senior level having already demonstrated these qualities. The position is available as early as August 1984 if a suitable candidate can be identified. Applications will be accepted at least until May 15, 1984, or until acceptable candidates are identified. Applications, including a resume and the names and addresses of four individuals who could serve as references, should be sent to: Professor Eugene H. Levy, Head, Department of Planetary Sciences, University of Arizona, Tucson, AZ 85721.

The University is an equal opportunity/affirmative action employer.

Research Associate. The Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, Colorado is advertising for a Research Associate position. The position description is as follows. The incumbent will initially participate as a member of a team of scientists in CIRES and NOAA involved in the development and calibration of two UV spectroradiometers for rocket-flight measurements of the solar UV spectral irradiance. This research is part of a program to determine the temporal variations of solar UV radiation, their stratospheric effects and possible effects on climate. The incumbent will participate in mountain-top measurements with the long-wavelength UV spectroradiometer to obtain direct intercomparisons at UV wavelengths with the mountain-top solar spectral irradiance measurements in the near UV, visible and infrared in collaboration with the University of Arizona. The incumbent will be responsible for the integration of the UV spectroradiometers into a rocket payload including developing the electronics interfaces with the sun-pointing system and the telemetry system. After the first rocket-flight measurements and depending on the experience of the incumbent, the incumbent's participation will range from a participating member of a team to being in charge of the follow-on rocket experiments, including the launch-site expeditions, recalibrations, and originating proposals to government agencies for rocket-flight and ground-station support.

The qualifications and desirable experience are as follows: a research scientist with a Ph.D. degree or equivalent in either physics, atmospheric science, astrophysics, meteorology, electrical or mechanical engineering with two years of research experience is required. Design and testing experience with electronics systems and microprocessors for use in the harsh environment of space, and for surviving the high-vibration environment of launch are required. Experience in vacuum UV spectroscopy, radiometry, rocket-flight, balloon-flight, shuttle-flight or satellite experiments on stratospheric research would be highly desirable. The salary range is $23,000–$30,000 depending on experience.

To apply for the position, applicants should submit a letter and complete resume including publications. In addition the applicant should request letters of recommendation from three individuals familiar with the applicant's personal and professional qualifications for the position. All application material should be forwarded to: Dr. Robert E. Sievers, Director, CIRES, Campus Box 449, University of Colorado, Boulder, Colorado 80309. The closing date for applications is April 15, 1984.

The University of Colorado is an affirmative action/equal opportunity employer.

Assistant Professor of Geophysics/Purdue University. The Department of Geosciences, Purdue University anticipates an opening for a new tenure track position at the assistant professor level in the area of exploration geophysics. The successful applicant must be prepared to assist in teaching exploration geophysics courses, advanced topics in his/her specialty and demonstrate an ability to develop and conduct productive research. Postdoctoral or industrial experience is desirable. The geophysics program in the Department of Geosciences at Purdue University currently consists of four full-time geophysics faculty. Field and laboratory equipment and facilities are available for application to seismological and potential field geophysical methods. Excellent computing facilities including a Cyber 205 computer operated by Purdue University and minicomputers within the Department of Geosciences are available.

Send letter of application including brief description of research interest and goals, resume and names of three references to: Don W. Levandowski, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907.

Closing date for acceptance of applications is May 1, 1984 or until the position is filled.

Purdue University is an equal opportunity/affirmative action employer.

Physicist. The National Oceanic and Atmospheric Administration (NOAA) announces a Physicist, GS-13, vacancy in the Environmental Research Laboratories, Space Environment Laboratory, Supporting Research Division, Boulder, Colorado. Starting salary at GS-13 level is $36,152. Duties include conducting research on the physics of the solar corona as related to the emission of matter and radiation which result in disturbances in the near-earth environment. Demonstrated achievement in basic astrophysical research is required. For further information and application procedures, please call Mary Plumley, NOAA Personnel at (303) 497-3102. Applications must be received by March 30, 1984, to be considered.

An equal opportunity employer.

University of New Mexico/Paleomagnetism. The Department of Geology of The University of New Mexico invites applications for a tenure track full-time position as an Assistant Professor with a specialty in paleomagnetism beginning Fall 1984. The successful candidate will be expected to maintain an active research program and teach at the undergraduate and graduate level. The Department has sixteen full-time faculty, is located in a spectacular natural setting and has excellent analytical facilities.

Applicants should submit a resume, transcripts, and three letters of recommendation to R. Ewing, Department of Geology, Albuquerque, New Mexico 87131. The deadline for applications is April 10, 1984.

The University of New Mexico is an equal opportunity/affirmative action institution.

Air Force Geophysics Laboratory Geophysics Scholar Program (1984–1985). The Air Force Geophysics Laboratory (AFGL) and The Southeastern Center for Electrical Engineering Education (SCEEE) announce that applications are invited for research appointments during the 1984–1985 year in the Geophysics Scholar Program. This program provides research opportunities of 10 to 12 months duration for selected Engineers and Scientists to perform research in residence at the AFGL, Hanscom AFB, near Boston, Massachusetts. Scholars will be selected primarily from such fields as Geophysics, Atmospheric Physics, Meteorology, Ion Chemistry, Applied Science, Mathematical Modeling using Computers, and Engineering.

The qualifications and desirable experience are as follows: ...

To be eligible, candidates must have a Ph.D. or equivalent experience in an appropriate technical field. Some appointments may be confirmed prior to August 1984 so early applications are encouraged. All qualified applicants will receive consideration without regard to race, color, religion, sex, or national origin. Application Deadline for September Appointments: August 1, 1984. For further information and application forms contact: SCEEE, 1101 Massachusetts Avenue, St. Cloud, FL 32769 Telephone: (305) 892-6146.

SCEEE supports Equal Opportunity/Affirmative Action.

Faculty Position/Florida Atlantic University. The Physics Department is soliciting applications for an experimental physicist in a tenure line position at the Assistant Professor level beginning August, 1984.

Candidates must have a Ph.D. degree and have demonstrated a commitment to research and teaching. Preference will be given to candidates with experience in experimental atmospheric physics, optics, or solid state physics.

Salary is negotiable. Deadline for applications—April 1, 1984. Contact Dr. [illegible], Chairman, Department of Physics, Florida Atlantic University, Boca Raton, FL 33431. Tel (305) 393-3381.

Florida Atlantic University is an affirmative action/equal opportunity employer.

Groundwater Hydrologist. Fulltime position. Ph.D. in Civil Engineering or Geohydrology with one to five years experience or M.S. with eight to ten years experience. Duties will consist of developing groundwater quality research ideas, seek funding and complete funded project. Basic geohydrologic skills required with strong emphasis on chemical background. Modeling skills desirable. Applicant must demonstrate good oral and written communication skills; be interested in developing own ideas and in assisting in staff management. Send resumes to: James P. Gibb, Head, Groundwater Section, Illinois State Water Survey, Box 5050, Station A, Champaign, IL 61820, 217-333-0236.

The State of Illinois is an affirmative action/equal opportunity employer.

University of Rochester/Postdoctoral Position in Low Temperature Geochemistry. The Department of Geological Sciences is an postdoctoral position for research on low-level, naturally occurring radioisotopes (Be-10, Cl-36, I-129, etc.). The research involves the separation of trace amounts of these elements with emphasis on the measurement of I-129 in a variety of materials to evaluate its potential as a tracer for fluid movements. Measurements will be carried out on the University's tandem accelerator.

The position is available immediately and is initially for one year with a possible one year extension. Send applications with resume and addresses of three references to:

Dr. Udo Fehn
Department of Geological Sciences
University of Rochester
Rochester, NY 14627.

The University of Rochester is an equal opportunity/affirmative action employer.

Geophysicist/Applied Mathematician, The University of Tulsa. The Departments of Geosciences and Mathematics invite applications for an anticipated senior position with a joint appointment in both departments. A proven record of research and teaching in mathematical geophysics, and/or mathematical physics is required. Experience in exploration geophysics data processing is desirable. The closing date is March 15, 1984. Send vitae and letters of reference to:

Edward Doze, Chairman
Department of Geosciences
The University of Tulsa
600 South College
Tulsa, Oklahoma 74104

The University of Tulsa has an equal opportunity/affirmative action program for students and employees.

Faculty Position/University of South Alabama. The Department of Geology and Geography is seeking to fill a tenure-track position at the Assistant Professor level, beginning September, 1984. Applicants should have major training and experience in geological application of remote sensing, and some phase of economic geology. The Ph.D. degree is required. This is a growing department with a present full-time faculty of five geologists and for geographers and approximately 200 majors. Please send resume and arrange for three letters of reference to be sent to: Dr. Glenn R. Sebastian, Chairperson, Department of Geology and Geography, University of South Alabama, Mobile, AL 36688. Applications should be sent before May 15, 1984.

The University of South Alabama is an equal opportunity, affirmative action employer.

Physical Oceanography/Skidaway Institute of Oceanography. A physical oceanographer with a Ph.D. is being sought to conduct research on the continental shelf. Preference will be given candidates with expertise in theoretical physical oceanography and who are interested in studying and modelling ocean-estuarine exchange processes and/or continental shelf circulation. Such studies will complement and guide experimental programs presently being conducted at the Institute. The selected applicant will be appointed at a level and salary commensurate with experience.

Interested persons are encouraged to submit a resume, the names of three individuals who can be contacted for reference purposes and a concise statement of research interests to: Dr. Jackson O. Blanton, (912)356-2457, Skidaway Institute of Oceanography, P.O. Box 13687, Savannah, GA 31416 before the deadline of March 30, 1984.

The Skidaway Institute of Oceanography is an equal opportunity/affirmative action employer.

Clay Mineralogy/University of Illinois at Urbana-Champaign. The Department of Geology invites applicants for a tenure-track faculty position in clay mineralogy. We are seeking candidates who have clearly demonstrated the potential to be outstanding researchers in the general areas of mineralogy, crystallography and chemistry of clay minerals, in the origin, diagenesis, and metamorphism of argillaceous sediments and whose future research will complement our existing programs in the petrology and diagenesis of sediments, experimental studies of compaction and of kinetics of burial diagenesis, behavior of clay minerals during deformation, petroleum geology, and stable isotope geochemistry. In addition to the development of a strong research program, the successful candidate is expected to participate in all aspects of teaching and advising at the graduate and undergraduate levels.

The Department of Geology houses a variety of facilities for clay mineralogy research, including x-ray diffraction and fluorescence units, an atomic absorption spectrophotometer, two NMR spectrometers, an isotope-ratio mass spectrometer, and electron microprobes. Numerous other analytical services are available on campus, particularly at the Materials Research Laboratory where there is equipment for Auger electron spectrometry, x-ray photoelectron spectrometry, scanning electron microscopy, transmission electron microscopy, and ion microprobe studies.

This position is available immediately. PhD. is required. Rank and salary will be commensurate with experience and qualifications. For equal consideration, please submit a letter of application that includes a statement of current and future research interests as well as a curriculum vitae, bibliography and the names of at least 3 references willing to comment on your qualifications and promise by April 1, 1984 to Dr. Albert V. Carozzi, Chairman, Search Committee, Department of Geology, 245 Natural History Building, 1301 W. Green Street, Urbana, IL 61801. Phone: 217/333-3008.

The University of Illinois is an equal-opportunity/affirmative action employer.

AGU MEMBERS

Moving? Call or write AGU with your change of address 6 weeks before your move.

Marine Geology and Geophysics/University of Washington. The School of Oceanography is seeking candidates for a position as Research Assistant Professor, but applications at a more senior level will be considered. Preference will be given to a candidate who has research interests in marine geology and geophysics and who will interact with our ongoing research projects, especially in the area of ridge-crest processes. Although this position will eventually be funded through self-generated research grants, partial financial support is available for the first two years. Teaching requirements will be limited and at the graduate level. For consideration, send a resume, a brief letter describing research interests, and four letters of reference by 1 May 1984 to:

Professor Brian T.R. Lewis
Director
School of Oceanography, WB-10
University of Washington
Seattle, WA 98195

The University of Washington is an affirmative action/equal opportunity employer.

Postdoctoral Position/Atmospheric Chemistry. A postdoctoral position is available for a person with a Ph.D. degree in chemistry (preferrably analytical or physical) or micrometeorology. The position involves the measurement of atmospheric acidity and the dry deposition of trace gases from towers and aircraft. The successful applicant will be expected to travel to a variety of field sites and to perform chemical analyses using ion chromatography. A facility with computer programming, the fabrication of research equipment, and careful chemical contamination-control would all be useful.

This is a two-year full-time position, with an annual salary of $15,000 during the first year, to begin in the summer of 1984. Interested persons should send a resume, names and phone numbers of three references, a statement of research interests, and any reprints to Barry Huebert, Department of Chemistry, Colorado College, Colorado Springs, CO 80903.

Colorado College is an equal opportunity employer.

STUDENT OPPORTUNITIES

Opportunity for Graduate Study in Igneous Petrology/Isotope Geochemistry—Southern Methodist University. The Department of Geological Sciences at Southern Methodist University in Dallas, Texas seeks outstanding individuals interested in a PhD program in igneous petrology and/or isotope geochemistry. The successful applicant should have a strong background in geology, chemistry, and mathematics and an interest in volcanic processes. Research will involve participation in a field-oriented petrological, geochemical, and isotopic study of Late Cenozoic volcanism in the Chilean Andes. For further details and applications please contact either:

Dr. R. S. Harmon (214) 692-3075
or
Dr. M. A. Dungan (214) 692-2752
Department of Geological Sciences
Southern Methodist University
Dallas, Texas 75275

State University of New York at Buffalo/Assistantship Opportunities. The Department of Geological Sciences invites graduate applicants for Fall 1984. Graduate Teaching assistantships offer a stipend up to $5500.00 for 10 months, plus tuition waiver. Special assistantships in geophysics, geocheimstry-mineralogy, and glaciology carrying a 10-month stipend of $7200.00 plus tuition waiver are available. Additional summer support is possible. Applications can be obtained from the Department of Geological Sciences, 4240 Ridge Lea, Amherst, NY 14226, 716-831-3051. Deadline for receipt of all materials is March 30, 1984.

The State University of New York at Buffalo is an affirmative action/equal opportunity employer and invites applications from minority and women candidates. No person in whatever relation with SUNYAB shall be subject to discrimination on the basis of age, color, national origin, race, religion, or sex.

AGU

AGU Congressional Science Fellow: Midterm Report

Jack Fellows

As the recipient of the 1983–1984 AGU Congressional Science Fellowship [*Eos*, September 6, 1983, p. 543] I have been asked to report on my midterm experiences. I have learned two major aspects of business on Capitol Hill. First, I am impressed by the tremendously important relationship between science and the political world of Congress. Congressmen need and actively seek technical advice on legislative issues. As a scientist, one's point of view can have an impact on society as well as on one's discipline.

Second, I have been overwhelmed by the dedication of members of Congress and their staff. As in corporations and academia, the politics and bureaucracy can suffocate many a good idea. However, considering these things, plus overlapping committee jurisdictions and the inherently difficult legislative process, it is still a wonder that Congress manages to produce anything.

The AGU Congressional Science Fellowship consists of four phases: selection, orientation, placement, and assignment. I would like to discuss each one of these phases; through each, I feel that I have learned and grown both personally and professionally.

Selection

Application required a letter of intent, vita, and letters of reference. Once short-listed, one wrote and presented a congressional briefing to a peer review board. I chose deep-seabed mining as my topic; it offered me the opportunity to show my ability to research a briefing on (to me) a totally foreign topic.

Orientation

In addition to AGU, 19 professional societies enroll their Fellows in the AAAS Congressional Orientation Program. These societies include the AGU, ACS, APhA, NSPE, IEEE, and others. This year there were 42 Fellows, ranging in age from 28 to 50. All but 10 of the Fellows have their doctorate.

Fellows have been placed in Congress, OTA, and the State Department. Besides constantly tapping our Fellows network (the Fellowship) for legislation information, we have regular dinner and luncheon seminars and informal meetings. We set up our own seminars, which have so far included topics like Central America, ethics, the "gender gap," arms control, risk assessment, and lobbying. I have had the great pleasure of being the chairman of this year's Fellowship.

The goal of orientation is to prepare one for placement in the personal office of a member, on a committee staff, or in some other congressional branch. This program is a rather grueling sequence of congressional briefings from congressional agencies, members of Congress, committee staffs, historians, AAAS representatives, former Fellows, and others. In addition, there are meals and receptions with speakers, members of Congress, and congressional staff. The Fellows' friendship develops through this exhausting but thoroughly enjoyable "boot camp." The AAAS orientation is similar to the orientation that freshman congressmen undergo. By the end of the 2-week period, one has a better understanding of how Congress is structured, how it operates, and what forces both emanate from Congress and shape Congress. The contact with congressmen and staff makes one aware of the important "players" in Congress. Now was the time for placement.

Interviews

We were now let loose on Capitol Hill to find a position for a year. All the interesting aspects of congressional work we had heard about during the orientation made it very difficult to chose the appropriate member, committee, subcommittee, or congressional branch. Prior to the orientation, I had chosen to work on hydrologically related issues. However, during orientation I had added to my list the areas of innovation, productivity, industrial policy, high-tech development, and foreign affairs.

AAAS provided us with a room full of phones in the Senate Hart Office Building, a list of congressmen looking for Fellows, and interview comments from last year's Fellows. The AAAS leadership and support are indispensable to the success of this program.

I left my condensed, one-page resume at more than 30 offices. I eventually interviewed with 13 personal offices and 6 committees on both the Senate and House sides. I went back to many of these offices two or three times. There was a constant exchange of interview information through the Fellowship network and relatively little competition. We found out a lot about ourselves, Congress, legislative issues, and especially the underground tunnels interconnecting the congressional office buildings.

In spite of all my criteria for choosing an office in which to work, my choice rested very heavily upon office "chemistry." I chose to work in the personal office of Rep. George E. Brown, Jr. (D-Cal).

Work

Besides being on the House Science and Technology Committee and the House Agricultural Committee, Rep. Brown has a personal interest in remote-sensing applications, water resources, and data base management, all of which I was involved in at the University of Maryland. Some of the other Fellows have told me that the members they work for do not even know their Fellows' name. I felt quite fortunate in this respect, because I get a chance to talk with Rep. Brown frequently and I have accompanied him on hearings and speech trips.

For the first 2 months, I read congressional reports, attended meetings, hearings, and floor debates and familiarized myself with

AGU (cont. on p. 78)

AGU *(cont. from p. 77)*

congressional and office procedures. I was given industrial policy, space, information, and water resources policy as issue areas. I was not given a specific project, except a speech on the role of the federal government in science and technology. During this time I helped on office projects and constituent work. (The volume of letters, requests, and information coming in to a congressional office is staggering.) I attended Congressional Research Service programs to familiarize myself with the Library of Congress and its data bases.

In November, Rep. Brown asked me to examine the possibility of drafting legislation for the commercialization of Landsat based on discipline resolutions and not the 80-m resolution of current proposals. I learned a great deal about possible suggestions at the National Telecommunications Conference and Jet Propulsion Laboratory.

However, after Congress adjourned in late November, I was asked to write four speeches on industrial policy, innovation, R&D, and productivity topics. The Landsat proposal was shelved for a while.

During the recess Rep. Brown also asked me to examine an Office of Technology Assessment recommendation that the United States needed a National Center for Water Resources Research modeled after the successful National Center for Atmospheric Research. I have made some proposals for such a structure that have generated interest with Rep. Brown, members of the Interior Committee, and the National Association of State Universities and Land Grant Colleges. The timing may actually be correct for this legislation. A lot of politics and arrangements must be worked out before such a bill will be introduced. However, this legislation has now become my main focus. The chances are small that it will make it to hearings before I leave, but I am endeavoring to lay the foundation.

I am enjoying the Hill very much. I know already it has had a great impact on my life. I know I will remain politically active when I return to the scientific community, and I would highly recommend this program to anyone regardless of profession or age.

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Raffi Aroian (P), David Baker (P), D. Craig Barilotti (O), Stephen J. Barnes (V), Thomas O. Barnwell (H), Robert P. Bessette (G), Brian Bicknell (H), William Blumberg (A), Michele A. Boccadoro (G), Richard Boylan (T), Robert C. Bucknam (T), Roman J. Budzianowski (H), Bruce M. Crowe (V), Charles G. Cunningham (V).

Calvin R. Dunlap (O), David M. Farmer (O), Terry Fundak (G), Oswaldo Garcia (A), Moises Garcia-Munoz (SC), Oktay Guven (H), Paul P. Hearn (H), K. V. Hodges (T), Kerry F. Inman (T), Tom Intrator (SS).

Richard Janda (H), Kathleen M. Johnson (V), Alan G. Jones (GP), Thierry Juteau (V), Peter Kearl (H), Tec Keith (V), W. J. Keith (V), Len Kobus (S), Randolph A. Koski (V), Donathon Krier.

Edward Laine (O), Kenneth K. Lajoie (T), Pasquale Lanciano (T), Timothy F. Lawton (T), James Leaird (S), Craig Lindberg (S), K. K. Liu (A), Mitchell W. Lyle (O), Peter Lysne (V).

Ann Maest (V), Maureen Mahoney (V), Marangu Marete (H), Claire Max (SS), Linda J. McAdams (S), Anne McCormack (H), Thomas P. Miller (V), M. Daniel Morrison (SA).

Richard K. Nishimura (V), Tatsuki Ogino (SM), Gautam Ojha (V), Stefano Orsini (SM), George A. Parks (H), Paul R. Passmore (S), J. P. Patel (GP), Jose M. Perez-Godos (H), James Robert Podolske (A), Benjamin J. Rice (T), James M. Roberts (A), David A. Seemann (O), Les E. Shephard (O), Andrew W. B. Siddans (T), Joel A. Silver (A), Stephen P. Smith (V), Claude James Sterling, R. N. Sundan (SS).

David J. Terrell (V), Robert H. Thomas (H), Yves M. Tourre (O), Michael Trainer (A), Taku Urabe (S), Jose Fco Valdes-Galicia (SC), Kunimiko Watanabe (SM), Lawrence Weiss (H).

Student Status

Jun Abrajano (V), Dave Boden (V), H. Herbert Breneman (SC), Mary F. Caress (V), Stefano Casotto (G), J. Vincent Eccles (A), Bruce Finney (O), Peter H. Gleick (A), Ann Isley (O), Sungtack Kwon (V), Ian Moxon, Kim Murphy (O), David W. Murray (O), Neil B. Myers (A).

Brian B. Quinn (S), Ingrid Reuber (T), Joseph Shields (SS), Carl L. Siefring (SA), Deborah K. Smith (T), Mary Streeter (S), Mohamed Sultan, Akiko Urabe (V), Ludovit Varga (SM), Jay D. Woosley (A).

AGU MEMBERS
Please write your member identification number on your check or money order to speed accurate processing by AGU.

Meetings

Announcements

Elevation Datums

Elevation datums are the subject of a 1-day program on March 13, 1984, at the annual meeting of the American Congress on Surveying and Mapping (ACSM) and the American Society of Photogrammetry in Washington, D. C. Jointly sponsored by ACSM, the American Association for Geodetic Surveying, and AGU's Geodesy Section, the session will feature 11 papers. Registration for the session at member rates will apply to AGU members. For further information, contact Thomas J. Lauterborn, Rte. 1, Box 127, Waterford, VA 22190, telephone 703-882-3334.

The paper titles and authors for the program are as follows:

Historical Overview of Vertical Datums, *Herbert W. Stoughton*
Geometrical Aspects of Vertical Datums, *J. D. Boal, F. W. Young, and R. Mazaachi*
Defining Vertical Datums: What Is Zero?, *Richard H. Rapp*
Aspects of a New Height System for North America, *Sandford R. Holdahl*
Fennoscandia Uplift, Plate Tectonics, and Seismicity, and Their Effects on Vertical Datums, *Larry Brown*
Definition: Oceanographic Approach, *Bruce C. Douglas and Robert E. Cheney*
The Determination of Geodetic Height From Laser Tracking Data, *David E. Smith and Demos C. Christodoulidis*
Deep Sea Techniques and Vertical Datums, *William E. Carter*
Gravimetric Approach to Defining Vertical Datums, *Lyman E. Wilcox*
NAVD 1988: A Status Report, *Charles T. Whalen*
The Administrative, Political, and Economic Aspects to Be Considered in the New Definition of the Vertical Datum, *John D. Bossler*

Geophysical Year

New Listings

June 11–12, 1984 **Fifth European Conference on Environmental Pollution**, Amsterdam. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7.)

July 5–6, 1984 **Second Symposium on Plasma Double Layers and Related Topics**, Innsbruck, Austria. (R. Schrittwieser, Inst. for Theoretical Physics, University of Innsbruck, Sillgasse 8, A-6020 Innsbruck, Austria.) **(The deadline for registering is May 1.)**

September 20–21, 1984 **International Symposium on Environmental Pollution**, Site To Be Announced. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7.)

September 24–26, 1984 **International Water Well Exposition**, Las Vegas, Nevada. Sponsor, National Water Well Association. (National Water Well Association, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

October 10–12, 1984 **Seismological Society of America Eastern Section 56th Annual Meeting**, St. Louis, Mo. (Robert B. Herrmann, Department of Earth and Atmospheric Sciences, St. Louis University, P.O. Box 8099, St. Louis, MO 63156; tel.: 314-658-3120.) **(Abstract deadline is September 4.)**

November 1984 **Mexican Geophysical Union Annual Meeting**, La Paz, Baja California Sur, Mexico. (Union Geofisica Mexicana, A.C., Comite Organizador Reunion 1984, Apartado Postal 1805, Ensenada 22800, B.C.N. Mexico.) **(Abstract deadline is August 1.)**

April 9–11, 1985 **Fifth Annual Front Range Branch Hydrology Days**, Fort Collins, Colo. (H. J. Morel-Seytoux, Dept. of Civil Engineering, Colo. St. Univ., Fort Collins, CO 80523; tel.: 303-491-5448 or 8549.)

June 26–28, 1985 **U.S. Symposium on Rock Mechanics**, Rapid City, S. D. Sponsor, South Dakota School of Mines and Technology. (Eileen Ashworth, Chairman, 26th U.S. Symposium on Rock Mechanics, Department of Mining Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701-3995; tel.: 605-394-2344.)

August 19–30, 1985 **23rd General Assembly of IASPEI**, Tokyo, Japan. (Ryosuke Sato, Secretary-General of the 23rd General Assembly of IASPEI, c/o Inter Group Corp., Akasaka Yamakatsu Bldg., 8-5-32, Akasaka, Minato-ku, Tokyo 107, Japan; tel.: Tokyo (03) 479-5311.)

The Geophysical Year calendar last appeared in the December 6, 1983, issue.

GAP

Separates

To Order: The order number can be found at the end of each abstract; use all digits when ordering. Only papers with order numbers are available from AGU. *Cost:* $3.50 for the first article and $1.00 for each additional article in the same order. Payment must accompany order. Deposit accounts available.

Send your order to
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009

Geochemistry

1620 Chemistry of bodies of water (fresh water)
STUDIES OF THE ANTHROPOGENICALLY ENHANCED CARBON CYCLE IN SURFACE FRESH WATERS
E. Degens (SCOPE/UNEP Intern. Carbon Center, Geol.-Paleont. Inst., Univ. of Hamburg, Bundesstr. 55, D-2000 Hamburg 13, Fed. Rep. Germany)
The carbon chemistry of rivers and lakes has been severely affected by man's activities. This is evident from the data base of the SCOPE/UNEP project "Carbon Transport in Major World Rivers". [illegible]

River Elbe, [illegible] manently. All [illegible] can additionally [illegible] genically [illegible] carbon cycle, [illegible] J. Geophys. Res., [illegible]

1440
Sr-Nd AND Rb-Sr SYSTEMATICS IN VOLCANICS AND ULTRAMAFIC XENOLITHS FROM MALAITA, SOLOMON ISLANDS, AND THE NATURE OF THE ONTONG JAVA PLATEAU
N. Bielski-Zyskind, G. J. Wasserburg (Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125), P. W. Nixon
A Rb-Sr and Sm-Nd study was carried out on ultramafic inclusions, [illegible] the Solomon [illegible] relatively undepleted mantle [illegible] depleted mantle [illegible] Theralite [illegible] undepleted mantle [illegible] exists at a [illegible] inclusion [illegible] LREE depleted [illegible] cannot be [illegible] subducted continental [illegible] that the [illegible] of old continental [illegible] a segment of [illegible] isotopic signature [illegible] (Nautiloid [illegible]) J. Geophys. Res., [illegible]

Geodesy and Gravity

1499 General (Spherical harmonic techniques)
THE EFFECT OF COORDINATE SYSTEM ROTATIONS ON SPHERICAL HARMONIC EXPANSIONS: A NUMERICAL METHOD
J. D. Goldstein (The Analytic Sciences Corp., 1 Jacob Way, Reading, Massachusetts 01867)
[illegible]
J. Geophys. Res., B, Paper 4B0165

Geomagnetism and Paleomagnetism

2599 General
DOMAIN WALL NUCLEATION AS A CONTROLLING FACTOR IN THE BEHAVIOR OF FINE MAGNETIC PARTICLES IN ROCKS
J. B. Moon, R. Fuller (Department of Geological Sciences, University of California, Santa Barbara, California 93106)
[illegible]
Geophys. Res. Lett., Paper 4L0015

Hydrology

3199 General (Hydrology)
"UPFACE" INFILTRATION OF SALT MARSHES: THEORY, MEASUREMENTS AND BIOGEOCHEMICAL IMPLICATIONS
Harold F. Hemond (Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139), William K. Nuttle, Roger W. Burke, Keith D. Stolzenbach
[illegible]
Water Resour. Res., Paper 4W0053

3199 General
ON THE PROBLEM OF PERMISSIBLE COVARIANCE AND VARIOGRAM MODELS
G. Christakos (Department of Civil Engineering, Polytechnic School, Athens, Greece)
[illegible]
Water Resour. Res., Paper 3W1855

Meteorology

3720 Climatology
ON THE VARIABILITY OF THE NET LONG-WAVE RADIATION AT THE OCEAN SURFACE
[illegible]

ture, humidity and cloud properties in the atmospheric column as well as at the surface. [illegible]

3720 Climatology
EFFECTS OF DYNAMICAL HEAT FLUXES ON MODEL CLIMATE SENSITIVITY
W.-C. Wang (Atmospheric and Environmental Research, Inc., Cambridge, MA 02139), G. Molnar and T. P. Mitchell, and P. H. Stone (Center for Meteorology and Physical Oceanography, MIT, Cambridge, MA 02139)
[illegible]
J. Geophys. Res., D, Paper 4D0234

Oceanography

4213 Circulation
MEAN CIRCULATION AND EDDY KINETIC ENERGY IN THE EASTERN NORTH ATLANTIC
W. Krauss (Institut für Meereskunde, Kiel, Germany), R. H. Käse
[illegible]
The centre of the gyre is located at about 35°N, [illegible]

Atlantic energy decreases east- and southwards and is [illegible]
J. Geophys. Res., C, Paper 4C0154

4765 Surface waves, tides and sea level
APPLICATIONS OF A SIMPLE NUMERICAL WAVE PREDICTION MODEL TO LAKE ERIE
David J. Schwab (Great Lakes Environmental Research Laboratory, NOAA, 2300 Washtenaw Ave., Ann Arbor, MI 48104), John A. Bennett, Paul C. Liu, and Mark A. Donelan
A parametric dynamical wave prediction model has been adapted and tested against semianalytic empirical results for steady conditions in a circular basin and extensive field measurements of wave height, period, and direction. [illegible]
J. Geophys. Res., C, Paper 4C0201

Particles and Fields—Interplanetary Space

5310 Cosmic Rays (Solar Modulation)
SOLAR MODULATION OF COSMIC RAY ELECTRONS 1978–1983
Paul Evenson (Bartol Research Foundation, University of Delaware, Newark, DE 19711), and Peter Meyer
[illegible]
J. Geophys. Res., A, Paper 4A0227

Particles and Fields—Ionosphere

5520 Electric fields
AN ENERGY PRINCIPLE FOR HIGH-LATITUDE ELECTRODYNAMICS
D.D. Barbosa (Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA 90024)
[illegible]
J. Geophys. Res., A, Paper 4A0238

interpretation of the solutions with relation to diverse observations and high-latitude phenomenology are included. (Electric fields, electric currents, ionosphere).
J. Geophys. Res., A, Paper 4A0225

5530 High latitude ionospheric currents
OPTICAL MAPPING OF IONOSPHERIC CONDUCTIVITIES
S. B. Mende (Lockheed Palo Alto Research Laboratory, 3251 Hanover Street, Palo Alto, California 94304), R. H. Eather, M. H. Rees, R. R. Vondrak, and R. M. Robinson
[illegible]
J. Geophys. Res., A, Paper 3A1874

5530 High-latitude ionospheric currents
ISEE-1 AND -2 OBSERVATIONS OF AN OSCILLATING OUTWARD MOVING CURRENT SHEET NEAR MIDNIGHT
T. L. Aggson (University of California, Los Angeles), C. T. Russell and F. J. Rich
[illegible]
J. Geophys. Res., A, Paper 4A0223

5560 Wave Propagation
NUMERICAL SIMULATIONS OF INTENSITY SCINTILLATION USING THE POWER LAW PHASE SCREEN MODEL
C. L. Rino (Radio Physics Laboratory, SRI International, 333 Ravenswood Avenue, Menlo Park, CA 94025), J. Owen
[illegible]
J. Geophys. Res., A, Paper 4S0231

5599 General (Equatorial Spread F)
RAYLEIGH-TAYLOR INSTABILITY IN THE PRESENCE OF A STRATIFIED SHEAR LAYER
P. Satyanarayana (Science Applications, Inc., McLean, Virginia 22102), P.N. Guzdar, J.D. Huba and S.L. Ossakow
[illegible]
J. Geophys. Res., A, Paper 4A0228

Particles and Fields—Magnetosphere

5715 Electric Fields
RELATIONSHIP OF DUSK SECTOR RADIAL ELECTRIC FIELD TO ENERGY DISTRIBUTION AT THE INNER EDGE OF THE ELECTRON PLASMA SHEET
J. L. Horwitz (Physics Department, The University of Alabama in Huntsville, Huntsville, Alabama 35899)
It is shown that, assuming conditions of approximate steady state and that the low-to-medium electrons forming the plasma sheet inner edge originate from a source in the magnetotail, the radial electric field in the dusk sector can be related to the radial energy dispersion of the plasma sheet inner boundary as

$$E_r = \frac{(\ldots)}{\ldots}$$

where (W_r) represents the energy of the electron inner boundary. [illegible]
J. Geophys. Res., A, Paper 4A0206

5739 (Magnetosphere)
THE DISTRIBUTION OF RECONNECTION GEOMETRY IN FLUX TRANSFER EVENTS USING ENERGETIC ION, PLASMA AND MAGNETIC DATA
P. W. Daly [illegible] AG Noordwijk [illegible] R.P. Rijnbeek [illegible]
A survey of [illegible] dayside [illegible]
J. Geophys. Res., A, Paper 4A0236

5770 Short-period variations of magnetic field
A SECOND-HARMONIC [illegible] THE [illegible] AND ISEE [illegible]
W.J. Hughes (Department of Astronomy, Boston University, Boston, MA 02215 [illegible])
We describe [illegible] ISEE 2 [illegible] observed [illegible]
J. Geophys. Res., A, Paper 4A0210

local geomagnetic field lines. ISEE 1 and 2 observed the opposite sense of polarization for about 30 min although the spacecraft were separated by only 9 min in their orbits; this remarkable feature cannot be explained by either a stationary spatial boundary or a simple temporal boundary but could result from a rapid movement of the resonant region. We argue that the most likely energy source in bounce resonance [illegible]
J. Geophys. Res., A, Paper 4A0246

5785 Whistlers
WAVE NORMAL DIRECTIONS OF CHORUS NEAR THE EQUATORIAL SOURCE REGION
R. R. Goldstein (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, 91109), and B. T. Tsurutani
[illegible]
J. Geophys. Res., A, Paper 4A0214

Journal of Geophysical Research

Volume 89 Number A3 March 1, 1984